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FILING DATE: *February 27, 2004*

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15750 U.S.PTO

PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53 (c).

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☒ *Additional inventors are being named on the* 1 *separately numbered sheets attached hereto*

TITLE OF THE INVENTION (280 characters max)

COMPUTER SYSTEM FOR AUTOMATED SCREENING AND DETECTION OF BONE FRACTURES IN DIGITAL X-RAY IMAGES

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ENCLOSED APPLICATION PARTS *(check all that apply)*

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☒ Application Data Sheet. See 37 CFR 1.76

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METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT *(check one)*

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The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

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Respectfully submitted,

SIGNATURE

Date 02/27/04

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Docket Number: 2500-000033

USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

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PROVISIONAL APPLICATION COVER SHEET
Additional Page

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Docket Number	2500-000033	Type a plus sign (+) inside this box →	+

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APPLICATION INFORMATION

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Title Line Two:: AND DETECTION OF BONE FRACTURES IN
Title Line Three:: DIGITAL X-RAY IMAGES
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Formal Drawings?:: Yes
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Secrecy Order in Parent Appl.?:: No

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Computer System for Automated Screening and Detection of Bone Fractures in Digital X-ray Images

Field

This invention relates to automated screening and detection of bone fractures in x-ray images.

Background

Many people suffer from fractures of the bone, particularly the elderly folks. According to the findings of the International Osteoporosis Foundation, the lifetime risk for osteoporotic fractures in women is 30% – 40% worldwide, and 13% in men. The number of hip fractures could rise from 1.7 million worldwide in 1990 to 6.3 million by 2050. Most dramatic increase is expected to occur in Asia during the next decades. According to World Health Organization, osteoporosis is second only to cardiovascular disease as a leading health care problem.

In clinical practice, doctors and radiologists in large hospitals rely mainly on x-ray images to determine the occurrence and the precise nature of the fractures. Visual inspection of x-rays for fractures is a tedious and time-consuming process. Typically, the number of images containing fractures constitutes a small percentage of the total number of images that the radiologists have to inspect. For example, in the x-ray images of femurs that we have worked on, only about 10% of them are fractured. After looking through many images containing healthy femurs, a tired radiologist has been found to miss a fractured case among the many healthy ones. Existing methods of performing detection of bone fractures include using: acoustic pulses (D. M. Ryder and S. L. King and C. J. Olliff and E. Davies, A possible method of monitoring bone fracture and bone characteristics using a non-invasive acoustic technique, In Proceedings of International Conference on Acoustic Sensing and Imaging, 1993, pages 159-163), mechanical vibration (J. J. Kaufman and A. Chiabrera and M. Hatem and N. Z. Hakim and M. Figueiredo and P. Nasser and S. Lattuga and A. A. Pilla and R. S. Siffert, A neural network approach for bone fracture healing assessment, IEEE Engineering in Medicine and Biology, volume 9, number 3, 1990, pages 23-30), and electrical conductivity (V. R. Singh and S. K. Chauhan, Early detection of fracture healing of a long bone for better mass health care, In Proceedings of Annual International Conference of IEEE Engineering in Medicine and Biology Society, 1998, pages 2911-2912).

Summary

As some fractures are easier to identify than others, an automated computer system can assist the doctors by performing the first examination to screen out the easy cases, leaving a small number of difficult cases and the second confirmation to the doctors. It can also alert the doctors to pay more attention to suspected cases of fractures. Automated screening of both healthy and fractured cases can thus relieve some of the labor-intensive work of the doctors and help to improve the timeliness and accuracy of their diagnosis. Therefore, this computer vision application is extremely useful for clinicians and is now feasible because all clinical radiology is going digital. Digital x-ray images are now routinely captured using digital x-ray machines.

At present, there is no existing commercial or research system that performs automated detection of bone fractures in digital x-ray images.

The invention provides a computer system for automated screening and detection of bone fractures in digital x-ray images. In particular, the system of one aspect can analyze digital x-ray images of the bones and perform the following tasks:

- Determines whether the bones are healthy or fractured, and computes confidence of the assessment;
- Identify cases suspected of fractures and highlight the possible areas where fractures may have occurred.

Additionally, the invention provides a computer system and associated software that perform the following tasks:

1. Reads digital x-ray images stored in an external storage device.
2. Identifies the regions of the images where the bones of interests are located.
3. Determines whether the bones of interests are fractured, and measures the confidence of the assessment.
4. For images that contain possibly fractured bones, marks the locations where fractures are suspected.
5. Displays on an output device the results of the automated analysis, including but not limited to
   - whether the bones of interests are fractured, and the associated confidence;
   - the locations of suspected fractures; and
   - alerting the doctors to the suspected fractures.

As discussed above, current clinical practice relies only on human inspection, and a tired radiologist has been found to miss a fractured bone among the many healthy ones. A computer system can help the doctors by screening for fractured cases and alert the doctors to pay more attention on suspected fractured cases.

Brief Description Of The Drawings

The accompanying drawings, which are incorporated into and constitute a part of the description of the invention, illustrate embodiments of the invention and serve to explain the principles of the invention. It is to be understood, however, that the drawings are designed for purposes of illustration only, and not as a definition of the limits of the invention for which reference should be made to the claims appearing at the end of the description.

1. Fig. 1 shows the computer system that reads in digital x-ray images from an external storage device, analyzes the images, and displays the results on an output device.

2. Fig. 2 shows the flow of processes in the computer that analyzes the x-ray images.
3. Fig. 3 shows an x-ray image of a femur.

4. Fig. 4(a) shows an x-ray image that contains a healthy femur with a normal neck-shaft angle. Fig. 4(b) shows an x-ray image that contains a fractured femur with a smaller-than-normal neck-shaft angle.

5. Fig. 5(a) shows the orientation map superimposed on the x-ray image of a healthy femur. Fig. 5(b) shows the orientation map superimposed on the x-ray image of a fractured femur.

Detailed Description Of The Preferred Embodiments

In detail now and referring to the drawings, Fig. 1 shows one embodiment of the present invention. The computer reads in digital x-ray images from an external storage device, analyzes the images, and displays the results on an output device.

Fig. 2 shows the flow of processes in the computer. The computer reads in an x-ray image, identifies the locations of the bones of interests, determines whether fractures exist in the bones of interests, measures the confidence of the assessment, marks the areas of suspected fractures, displays the analysis results, and alerts the doctors to the suspected fractures.

In an embodiment of the invention, the process of identifying the locations of the bones of interests consists of applying (1) the Active Shape Model (T. F. Cootes and A. Hill and C. J. Taylor and J. Haslam, The use of active shape models for locating structures in medical images, Image and Vision Computing, volume 12, number 6, 1994, pages 355-366) to determine the initial guess of the outer contour of the bones, (2) the Active Appearance Model (T. F. Cootes and G. J. Edwards and C. J. Taylor, Active Appearance Models, Proceedings of European Conference on Computer Vision, 1998) to determine accurate landmark locations along the initial guess of the bone contour, (3) refinement of the bone contour to determine to exact contour of the bone.

In an embodiment of the invention, the refinement of the bone contour is performed using Iterative Closest Point method (P. J. Besl and N. D. McKay, A method for registration of 3-D shapes, IEEE Transactions on Pattern Analysis and Machine Intelligence, volume 14, number 2, 1992, pages 239-256).

In another embodiment of the invention, the refinement of the bone contour is performed using Active Contour (i.e., Snake) method (M. Kass and A. Witkin and D. Terzopoulos, Snakes: Active Contour Models, International Journal of Computer Vision, volume 1, 1987, pages 321-331).

In an embodiment of the invention, the process of determining whether fractures occur consists of a combination of two or more methods, each examining different aspects of the x-ray image of the femur (Fig. 3).

The first method measures the neck-shaft angle of the femur by (1) determining the femoral neck axis, (2) determining the femoral shaft axis, and (3) measuring the obtuse angle made by the neck axis and the shaft axis. Images with neck-shaft angle smaller than a pre-specified angle are flagged as suspected fractured cases (Fig. 4). The difference between the measured angle and the pre-specified angle is regarded as a measure of the confidence of the assessment.

The second method computes a feature map that records visual features at various locations of the femur image. A mean feature map is then computed by averaging the feature maps of sample healthy femur images. To determine whether a fracture exists, the difference between the feature map of an input femur image and the mean feature map is performed to produce the difference map. Then, the difference map is classified by the Support Vector Machine (C. Cortes and V. Vapnik, Support vector networks, Machine Learning, volume 20, 1995, pages 273-297) to determine whether a fracture exists. The

distance between the difference map and the hyperplane computed by the Support Vector Machine is regarded a measure of the confidence of the assessment.

In an embodiment of the invention, the feature map records the orientations of the trabecular lines at various locations in the femur image (Fig. 5). The orientations are computed by filtering the image with a set of Gabor filters with different orientation preferences (A. C. Bovik and M. Clark and W. S. Geisler, Multichannel texture analysis using localized spatial filters, IEEE Transactions on Pattern Analysis and Machine Intelligence, volume 12, number 1, 1990, pages 55-73). At each location, the orientation of the Gabor filter with the largest response indicates the orientation of the trabecular lines at that location.

In another embodiment of the invention, the feature map records the Markov Random Field texture features (G. R. Cross and A. K. Jain, Markov random field texture models, IEEE Transactions on Pattern Analysis and Machine Intelligence, volume 5, 1983, pages 25-39) at various locations in the femur image.

In another embodiment of the invention, the feature map records the directions and magnitudes of the intensity gradients at various locations in the femur image.

References and Prior Art

List of references:

- T. F. Cootes and A. Hill and C. J. Taylor and J. Haslam, The use of active shape models for locating structures in medical images, Image and Vision Computing, volume 12, number 6, 1994, pages 355-366.
- T. F. Cootes and G. J. Edwards and C. J. Taylor, Active Appearance Models, Proceedings of European Conference on Computer Vision, 1998.
- P. J. Besl and N. D. McKay, A method for registration of 3-D shapes, IEEE Transactions on Pattern Analysis and Machine Intelligence, volume 14, number 2, 1992, pages 239-256.
- M. Kass and A. Witkin and D. Terzopoulos, Snakes: Active Contour Models, International Journal of Computer Vision, volume 1, 1987, pages 321-331.
- C. Cortes and V. Vapnik, Support vector networks, Machine Learning, volume 20, 1995, pages 273-297.
- A. C. Bovik and M. Clark and W. S. Geisler, Multichannel texture analysis using localized spatial filters, IEEE Transactions on Pattern Analysis and Machine Intelligence, volume 12, number 1, 1990, pages 55-73.
- G. R. Cross and A. K. Jain, Markov random field texture models, IEEE Transactions on Pattern Analysis and Machine Intelligence, volume 5, 1983, pages 25-39.

Fig. 1

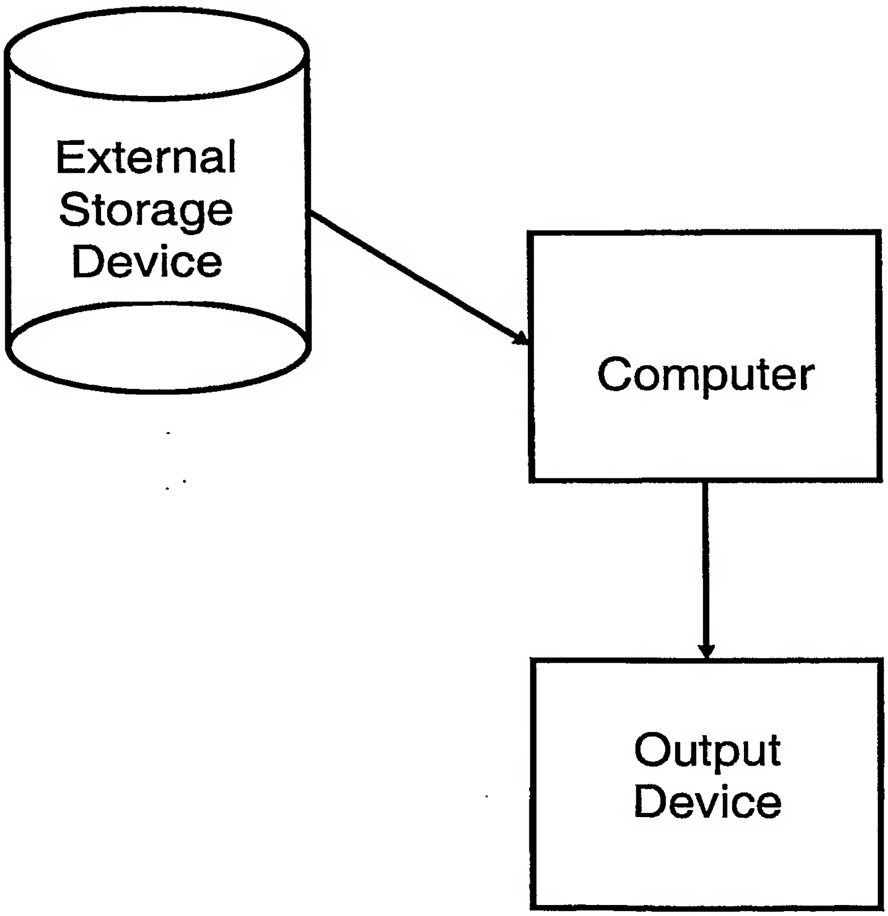


Fig. 2

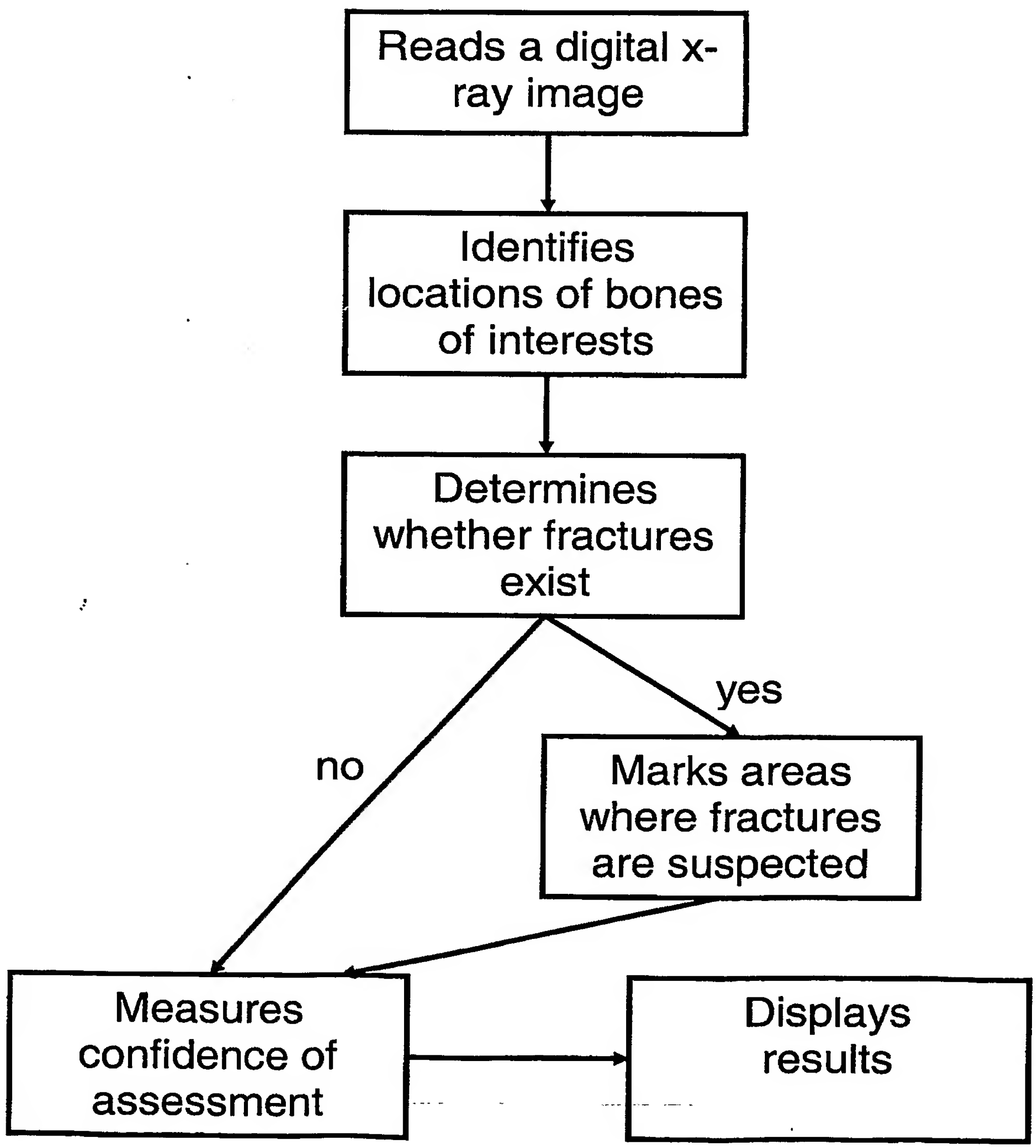

Reads a digital x-ray image
Identifies locations of bones of interests
Determines whether fractures exist
yes
no
Marks areas where fractures are suspected
Measures confidence of assessment
Displays results

Fig. 3

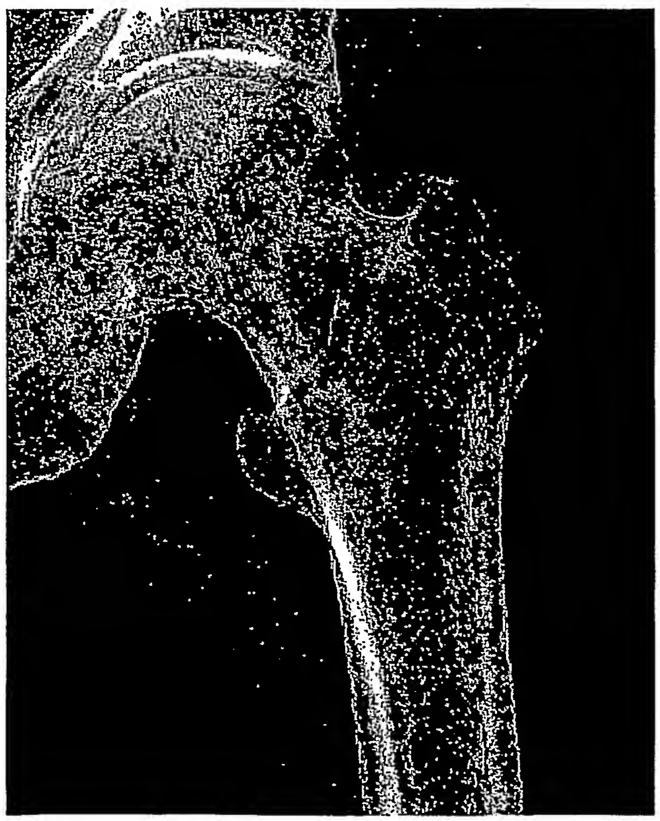


Fig. 4

(a) (b)

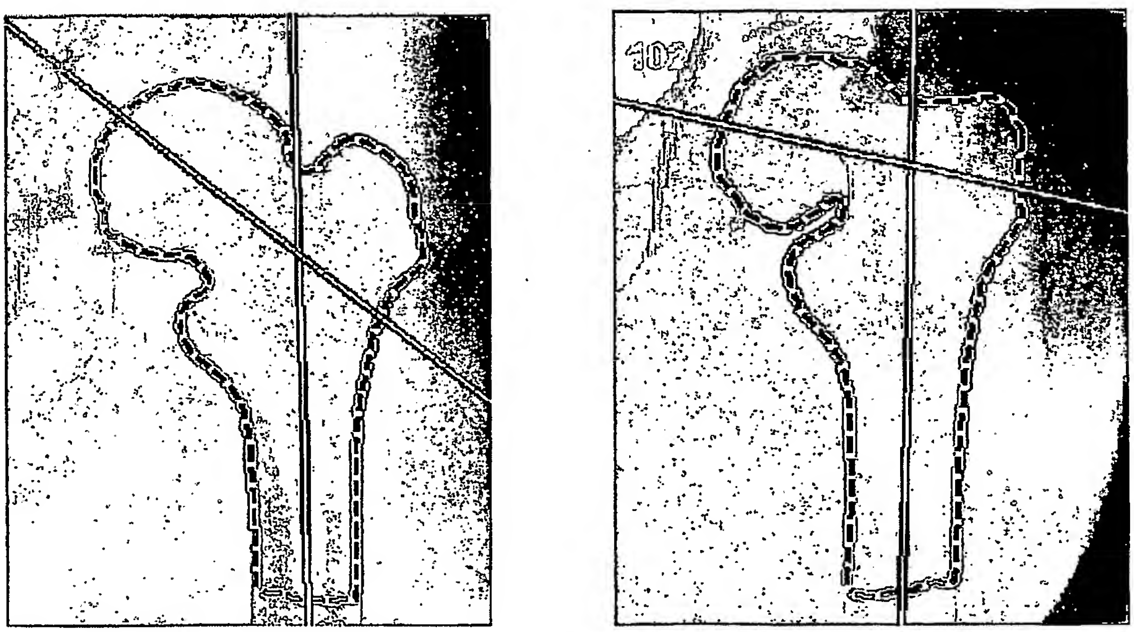
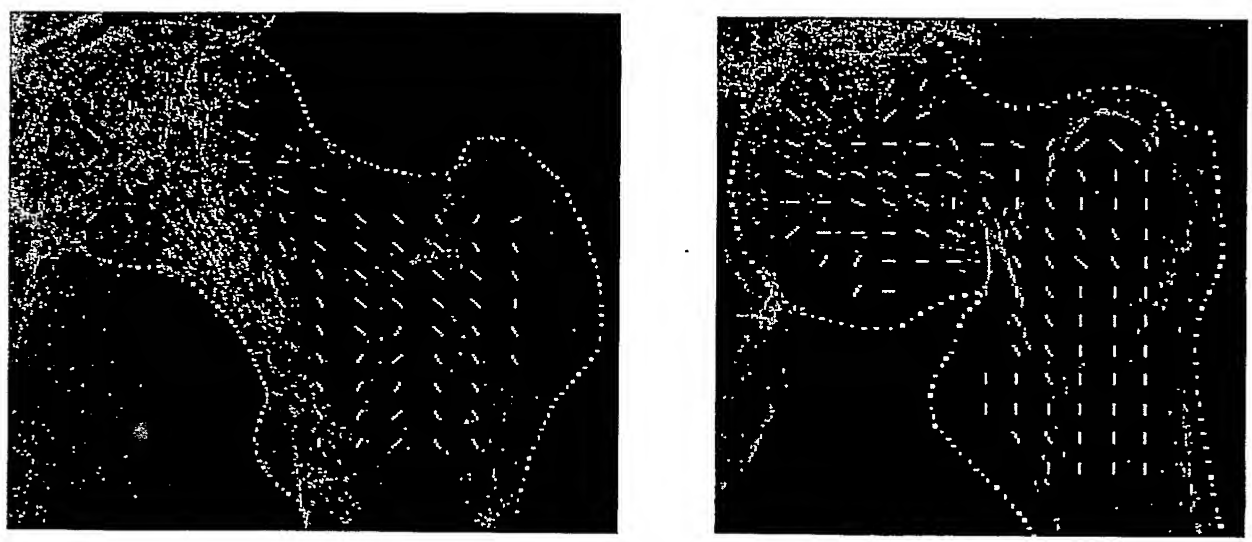


Fig. 5

(a) (b)



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